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AFATL-TR-71-148

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**FEASIBILITY OF AN ALL-SECONDARY-
EXPLOSIVE, LOW-VOLTAGE, ELECTRIC
DETONATOR**

SYSTEMS, SCIENCE AND SOFTWARE

**WARHEAD AND EXPLOSIVES BRANCH
AIR FORCE ARMAMENT LABORATORY**

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TECHNICAL REPORT AFATL-TR-71-148

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**Feasibility Of An All-Secondary-
Explosive, Low-Voltage, Electric
Detonator**

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Systems, Science And Software

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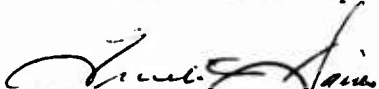
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FOREWORD

This final report documents work performed during the period 22 December 1970 through 31 December 1971 by Systems, Science and Software, P. O. Box 1960, La Jolla, California, under Contract F08635-71-C-0064 with the Air Force Armament Laboratory (AFATL), Air Force Systems Command, Eglin Air Force Base, Florida. Major Duncan E. Dodds (DLIW) monitored the program for the Armament Laboratory. Mr. Robert J. Reithel of Clovis, New Mexico, provided technical assistance to the program.

Air Force testing of prototype detonators furnished under this program was accomplished during the period 3 November 1971 to 5 November 1971 by personnel of the AFATL Explosive Dynamics Laboratory, Eglin Air Force Base, Florida, under the direction of Major Milton H. Purdy (DLIW).

This technical report has been reviewed and is approved.



FRANKLIN C. DAVIES, Colonel, USAF
Chief, Flame, Incendiary, and Explosives Division

ABSTRACT

The feasibility of an all-secondary-explosive, low-voltage, electric detonator was demonstrated. The detonator consists essentially of a donor explosive combustion chamber, an impactor disc, an air-gap and an acceptor explosive column which provides for proper coupling of the following three critical processes:

- (1) Hot-wire initiation of a self-sustaining deflagration in a "donor" secondary explosive.
- (2) Release and acceleration of a metal impactor disc by confined product gases of the deflagration in the donor secondary explosive.
- (3) Shock initiation-to-detonation of an acceptor secondary explosive upon impact by the accelerated impactor disc.

The design parameters controlling the critical processes are discussed. Unique safe and arm mechanisms, inherent in the basic detonator concept, were also investigated, and are described.

Prototype detonators furnished under this program were function tested by the Armament Laboratory with satisfactory results.

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SECTION I

INTRODUCTION

The objective of this program was to develop a low-voltage detonator containing no primary explosive. The detonator is based on hot wire initiation-to-deflagration of a secondary-explosive donor charge (RDX). The deflagration-to-detonation transformation within the detonator is accomplished via a high-velocity impactor disc striking and initiating an acceptor charge of an approved booster explosive.

Detonators normally consist of a spark or heat-sensitive primary explosive and a booster charge. The booster charge, which is a secondary explosive, provides the main impulse of the detonator. The primary explosive is usually lead azide, lead styphnate or mercury fulminate.

The sensitivity of primary initiating explosives to shock, spark, and impact necessarily introduces hazards in manufacture and use requiring elaborate precautions to insure safety in handling. Mercury fulminate is well known as being thermally unstable, and has been replaced generally by lead azide. However, lead azide is susceptible to hydrolysis which, in the presence of copper, results in the formation of very sensitive corrosion products. Unless stored under proper conditions, therefore, detonators containing mercury fulminate or lead azide have a limited shelf life. Lead styphnate is much more stable chemically, but presents serious hazards due to its sensitivity to electrostatic charge, under conditions now known to exist in some types of electric detonators (Ref. 1).

In addition, primary explosives, with few exceptions, do not burn; they detonate. Friction and fire can lead to detonation in adjoining secondary explosives. The high sensitivity of primary explosives dictates that detonators be handled and stored separately from munitions whenever possible.

Secondary explosives show much reduced mechanical sensitivity, good chemical stability, and, in general, very little hazard associated with electrostatic conditions. The use of only secondary explosives in detonators would reduce the hazards of handling detonators to the same level as handling the main charge. With suitable high-initiation levels and simple shuttering (explosive train interruptor), a detonator containing only secondary explosives could be safely

mated with munitions during manufacturing, greatly simplifying logistics and field handling of such munitions.

One possible solution to these problems is an exploding wire detonator which contains no primary explosives and which requires a tailored electrical pulse to properly explode the wire and cause initiation of detonation. These devices, with properly designed high-voltage/power/energy source and switch assembly, are costly and complex when compared to hot-wire detonators and associated low-voltage/power/energy supplies. Their use would impose significant changes in the power supply and firing circuit of conventional fuze system.

This report describes the development and feasibility demonstration of an all-secondary-explosive, low-voltage, electric detonator, which requires little, if any, perturbation to the power supply and firing circuit.

Air Force testing of prototype detonators furnished under this program is documented in Appendix II.

SECTION II

PRINCIPLES OF OPERATION

The all-secondary-explosive, low-voltage, electric detonator results from proper coupling of the following three processes:

- Hot-wire initiation of a self-sustaining deflagration in a "donor" secondary explosive.
- Release and acceleration of a metal impactor disc by confined product gases of the deflagration in the donor secondary explosive.
- Shock initiation-to-detonation of an acceptor secondary explosive upon impact by the accelerated impactor disc.

These three processes have been demonstrated separately (Ref. 2, 3, and 4) and together (Ref. 1 and 5) in previous laboratory experiments.

A. Hot-Wire Initiation of Self-Sustaining Deflagration

Efficient hot-wire initiation of a self-sustaining deflagration in a secondary explosive such as RDX, requires that the reaction product gases be confined so that the reaction pressure can rapidly increase and overcome the influence of divergence in the small volume of explosive ignited by the hot wire. Experiments have shown that suitable confinement of the product gases can be obtained by enclosing the wire and explosive in a heavy container, and by pressing the explosive to a high density in intimate contact with the wire and container (Ref. 2 and 5).

B. Impactor Disc Release and Acceleration

A deflagration can be converted to a detonation by inserting a mechanical link into the chemical system. The high-pressure product gases from the deflagration are used to expel and accelerate a thin metal disc across an air-gap. The impactor disc then strikes an acceptor explosive and the impact-generated shock initiates detonation.

In order to illustrate the impactor disc velocities which are attainable in distances and times of interest, assume a stainless steel flyer plate with a thickness h of

0.005 inch (0.0127 cm) and a diameter d of 0.2 inch (0.508 cm). The density ρ of steel is about 7.9 gm/cm^3 and the shear strength σ_s is about $4 \times 10^9 \text{ dynes/cm}^2$. Further assume that a steady pressure P of about 20,000 psi ($1.38 \times 10^9 \text{ dynes/cm}^2$) is available during the acceleration of the flyer across a gap s of 0.2 inch (0.508 cm).

The pressure P necessary to release the impactor disc is

$$P = \frac{\sigma_s (\text{area to be sheared})}{(\text{area over which } P \text{ acts})}$$

$$P = \frac{\sigma_s \pi d h}{\pi d^2 / 4}$$

$$P = \frac{4 \sigma_s h}{d}$$

For the values in our illustration,

$$P = 4 \times 10^8 \text{ dynes/cm}^2.$$

The acceleration experienced by the impactor disc is

$$a = \frac{P d^2 / 4}{\rho h d^2 / 4}$$

$$a = \frac{P}{\rho h}$$

$$a = 1.38 \times 10^{10} \text{ cm/sec}^2.$$

The time to transit 0.508 cm is then

$$t = \frac{2s}{a}$$

$$t = 8.6 \times 10^{-6} \text{ sec}$$

and the final velocity is

$$V = at$$

$$V = 1.2 \times 10^5 \text{ cm/sec.}$$

Thus, impact velocities of at least one mm/ μsec may be achieved.

C. Initiation of Detonation by Impact

Shock initiation of solid explosives has been investigated quantitatively for several explosives over a range of shock strengths and shock pressure durations (Ref. 6, 7, 8, and 9). Also, the Hugoniot of several explosives (Ref. 6, 9, 10, 11 and 12) have been determined such that the strength of impact generated shocks can be estimated in terms of the particular explosive and the material and velocity of the impactor.

Seay and Seely (Ref. 6) obtained detonation in a 1.0 gm/cc pressing of PETN with stress of about 4 kbar. This stress corresponds to that which would result from impact with a brass plate moving at about 0.4 mm/ μ sec. Lindstrom (Ref. 9) detonated 1.6 gm/cc tetryl with a stress of about 50 kbar, a stress which would result from impact with a brass plate moving at about 1 mm/ μ sec.

Continue the numerical illustration where it was shown that impact velocities greater than 1 mm/ μ sec could be obtained with a 0.0127-cm thick stainless steel impactor disc moving a distance of 0.508 cm. When a disc with a velocity of 1 mm/ μ sec impacts, for example, plastic-bonded RDX (94%RDX/6%EXON) with a density of 1.6 gm/cm³, a stress wave of about 47 kbar is transmitted into the explosive (Ref. 13) (the brass impactor disc used in Reference 12 is approximately equivalent in impedance to stainless steel). Experiments with thick shock waves resulted in detonation after the shock propagated about 0.08 cm into the explosive. This took about 0.2 μ sec. Detonation was obtained in 0.3835 cm and 1.2 μ sec with an initial shock pressure of 18 kbar in the explosive (Ref. 13).

SECTION III

DETONATOR DEVELOPMENT PROGRAM

A. Design Specifications

Development of the all-secondary-explosive, low-voltage, electric detonator required variation of parameters controlling the three processes previously discussed to meet the detonator design specifications. The design specifications are:

- (1) Detonator Safety. The detonator design shall meet the design criteria of MIL-STD-1316 (Navy).
- (2) Initiation. The detonator shall be designed to be capable of electrical initiation only. The maximum all-fire current shall not exceed ten amperes. The minimum no-fire current shall be no less than one ampere applied for one minute.
- (3) Reaction Time. The detonator shall have a reaction time of 1.0 millisecond or less. Reaction time is defined as the time differential between application of the initiating current and breakout of the detonation wave from the acceptor charge.
- (4) Explosive Components. The detonator shall contain a secondary explosive no more sensitive to impact, shock, friction or spark than HMX or RDX as the donor charge. The acceptor charge shall be one of the explosives listed as acceptable in MIL-STD-1316.
- (5) Dimensions and Materials. The outside dimensions of the detonator shall not exceed 5/8 inch in diameter by 1-1/4 inch in length. (Dimensions of 3/8 inch in diameter by 3/4 inch in length are desired.) The materials used to fabricate metal parts for the detonator shall conform to paragraphs 5.2 and 5.3 of MIL-STD-320. Nonpermissible couples defined in MIL-STD-889 shall not be used.
- (6) Performance. The detonator must produce dents in excess of 0.010 inch when tested

in accordance with Test 301, MIL-STD-331.
(Feasibility shall be demonstrated when five consecutive detonators meet this requirement.)

- (7) A ten-year shelf life shall be a design objective for the detonator.

B. Design Parameters

The selection of the donor explosive, acceptor explosive, explosive densities, air-gap, impactor disc and bridgewire dimensions are all closely related and permit a large degree of design flexibility to meet the design specifications.

Several donor explosives have been studied (Ref. 2 and 3), including RDX, HMX, PETN, Tetryl, DATB, TNT, Nitroguanidine, and Nitromethane. RDX was arbitrarily selected for the detonator development and feasibility demonstration because, of the three most studied explosives, it is more stable at higher temperatures than is PETN and because its high temperature behavior is not complicated by a polymorphic phase change, as is that in HMX. The density of the donor explosive can be varied over a wide range, but the lower densities require more electrical energy for initiation of deflagration and they require more external confinement.

The characteristics of the impactor disc and the length of the air-gap are related and permit design trade-offs. A thick disc requires either a higher pressure or more distance to attain the necessary impact velocity for initiation of the acceptor. On the other hand, an impactor disc may be so thin that the resulting short duration shock in the acceptor will not reliably cause detonation. Stainless steel was selected as the impactor disc material because of its strength, availability and chemical inertness.

The length of the air-gap was chosen to assure acceleration to an impact velocity higher than that necessary for prompt initiation of the acceptor charge. The required area of the impactor disc and air-gap is dependent on the initiation properties of the acceptor explosive. Shock initiation behavior of secondaries is a function not only of the stress amplitude but of the duration and radius of the curvature (divergence) of the initiation shock wave. For example, if a low-density acceptor explosive were used, it could be initiated with a weaker shock than could a high-density acceptor, but greater duration and less divergence of the shock would be required.

The electrical requirements and, consequently, all-fire and no-fire conditions can be controlled by varying the size and material of the bridgewire (Ref. 4) and by varying the density and material of the donor explosive (Ref. 2 and 3). The 0.0015-inch diameter platinum bridgewire was selected because, with 1.6 gm/cm³ RDX, it is expected to fulfill a one-ampere no-fire current specification while requiring modest operating energy.

C. Detonator Development

A baseline configuration of the all-secondary-explosive, low-voltage, electric detonator was designed and built (Figure 1). Development of the detonator was accomplished in a series of experimental tests to evaluate the behavior of the three critical processes. The results of each test series were then evaluated to define modifications to the baseline configuration to improve the interaction of the critical processes. This serial development allowed a logical and controlled evolution of the detonator.

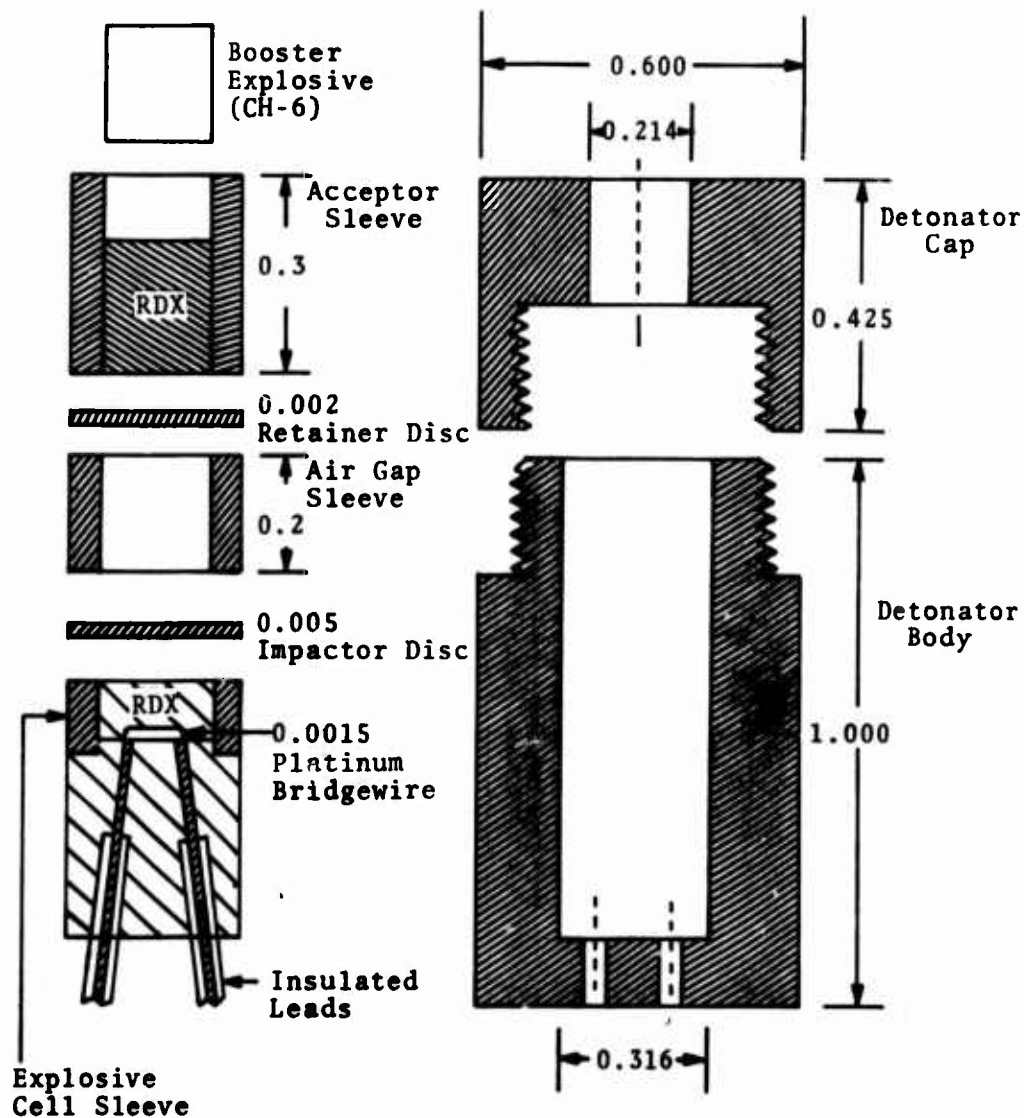
The development effort stressed, in sequential order:

- (1) Repeatable donor ignition.
- (2) Acceptor initiation and detonation with specified output requirement.
- (3) Safe and arm configurations.

A summary of the development program, configuration revision, and results is shown in Table I.

Repeatable donor ignition (self-sustaining deflagration in the pressed pellets of granular RDX) was the major difficulty encountered in demonstrating the feasibility of the detonator. The two parameters controlling this process are:

- (1) Sufficient confinement (gas product containment) to support that threshold pressure required for a self-sustaining deflagration in the pressed pellet of granular explosive (RDX).
- (2) A source of heat of sufficient temperature and persistence to decompose enough of the explosive to attain that threshold pressure within the heated volume of the explosive (Ref. 5).



NOTE: All dimensions in inches

Figure 1. Detonator Baseline Configuration

TABLE I. SUMMARY OF THE DETONATOR DEVELOPMENT PROGRAM

Detonator Configuration	Test Samples	Donor Ignition	Acceptor Detonation	Major Configuration Changes	Objective
Baseline	8	1	0		Baseline Test
Revision 1	5	0	0	Reduced RDX particle size	Increase surface area
Revision 2	8	1	0	Header material changed from Micarta to DAP and/or Mycalex [®]	Reduce Thermal Loss
Revision 3	14	4	0	Reduced internal air gap from 0.2 to 0.125 or 0.150 ID	Improve gas product containment
Revision 4	8	3	0	Modified electrode insert	Improve gas product containment
				Specified 0.003 inch overfill of donor charge	Improve gas product containment
				Modified donor explosive loading technique	Improve gas product containment

TABLE I. SUMMARY OF THE DETONATOR DEVELOPMENT PROGRAM (Continued)

Detonator Configuration	Test Samples	Donor Ignition	Acceptor Detonation	Major Configuration Changes	Objective
Revision 5	13	9	0	Modified body and cap to permit use of torque wrench Modified donor explosive cell insert sleeve to 6061-T6 aluminum Increase impactor disc thickness to 0.007 inch	Improve gas product containment Improve gas product containment Improve gas product containment
Revision 6	9	8	1	Selection of approved acceptor explosive	Comply with MIL-STD-1316
Revision 7	9	8	3	Impactor disc thickness increased to 0.023 inch Removed retainer disc Shaped acceptor charge	Improve acceptor detonation Improve acceptor detonation Improve acceptor detonation

TABLE I. SUMMARY OF THE DETONATOR DEVELOPMENT PROGRAM (Concluded)

Detonator Configuration	Test Samples	Donor Ignition	Acceptor Detonation	Major Configuration Changes	Objective
Safe & Arm No. 1	5	2	0	Rotary safe & arm mechanism (in arm position)	Provide safe & arm capability
Safe & Arm No. 2	5	4	0	Small rod safety mechanism (pulled for arm)	Provide safe & arm capability
Safe & Arm No. 3	6	6	0	Safety barrier moved higher in air gap	Provide safe & arm capability
Final Configuration	9	7	7	(Revision 7 configuration)	Design proof performance test

The baseline detonators that failed to achieve donor ignition were disassembled and inspected. These detonators exhibited charring of the donor explosive adjacent to the bridgewire, discoloration and decomposition of the header material, and fusing of the bridgewire. These anomalies indicated a loss of thermal energy to a level below that required to decompose a sufficient amount of RDX to self-sustain deflagration.

Revision 2 configuration of the detonator utilized a header material with improved thermal characteristics and a smaller particle size of RDX. These modifications to the baseline configuration corrected the apparent thermal loss problem but did not improve donor ignition.

The crucial parameter for donor ignition is sufficient gas product containment to achieve the threshold pressure for a self-sustaining deflagration. The detonator design was reviewed for mechanical and assembly weaknesses which could result in pressure relief. Pressure relief could possibly occur by deformation of the impactor disc, air-gaps during assembly, venting, and similar physical mechanisms. Specific design changes to correct these deficiencies and provide positive gas product containment are shown in Table II.

Detonator Revision 5, a culmination of refinements to improve gas product containment so that the donor explosive could self-sustain its deflagration, demonstrated repeatable donor ignition. The donor explosive was RDX, per MIL-R-398C, with a particle size of 100 microns and pressed to a density of 1.65 to 1.67 gm/cc. Reithel, in previous work (Ref. 5) on RDX deflagration, used Class A RDX of 99.3 percent purity reprecipitated by the addition of a solution of RDX-dimethylsulfoxide to water. This particular type of RDX was unavailable. It is possible that the specific impurities in the reprecipitated RDX and the particle size and shape provide an explosive which is more easily ignited than MIL-R-398C.

After demonstrating repeatable donor explosive ignition, emphasis was placed on achieving successful detonation of the acceptor explosive. The acceptor explosive (PBXN-5) was selected from the approved booster explosive list specified in MIL-STD-1316. The impactor disc thickness was increased to 0.023 inch from the baseline configuration of 0.005 inch. The force required to rupture the disc was thus increased, and the duration of the impact generated shock was increased. The acceptor explosive of Revision 7 detonators was shock-initiated to detonation within the

TABLE II. DESIGN CHANGES TO IMPROVE GAS PRODUCT CONTAINMENT

Detonator Configuration	Configuration Change	Objective
Revision 3	Reduced internal air gap from 0.2 to 0.125 or 0.150 ID	Reduce possibility of venting by impactor disc deformation at periphery
	Modified electrode insert	Provide an improved epoxy/header interface to prevent movements of electrodes and possible pressure relief
	Specified 0.003 inch overfill of donor charge	Remove possibility of air gap at RDX/impactor disc interface
Revision 4	Modified donor explosive loading	Changed loading technique from loading donor explosive cell externally to loading donor explosive cell after assembly into detonator body to remove possibility of deformation of cell under loading pressures
Revision 5	Modified body and cap to permit use of torque wrench	Permit consistent and repeatable force applied to impactor disc periphery for gas product containment
	Modified donor explosive cell insert sleeve with 10° chamfer	Provide sealing surface for impactor disc to prevent venting of gas products
	Changed donor explosive cell insert sleeve to 6061-T6 aluminum	Provide deformation of sealing surface, during assembly, for positive gas seal
	Increase impactor disc thickness to 0.007 inch	Reduce possibility of pressure relief by deformation of impactor disc at center

specified response time and required performance output. The completion of this test series verified the validity of the basic detonator concept.

D. Safe and Arm Configuration

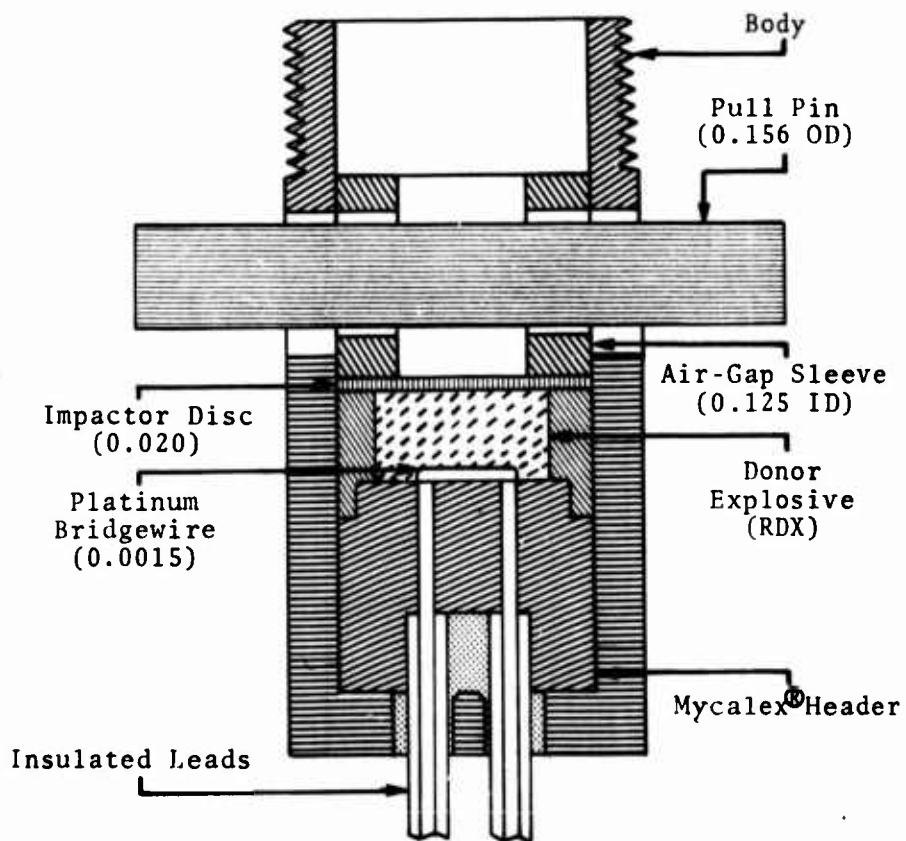
The air-gap, an essential part of the detonator concept, offers a unique opportunity for development of a safe and arm (S&A) system which will not disturb any interfaces in the explosive train when operated. A mechanical barrier can be inserted to intercept the impactor disc and prevent the disc from shock initiating the acceptor explosive. Two different S&A mechanisms, a simple slide barrier (Figure 2) and a rotary mechanism (Figure 3), were designed, fabricated, and tested. The first test series of the rotary mechanism indicated insufficient gas product containment for repeatable donor ignition. This was probably caused by weakening of the spacer sleeve. The S&A detonator configurations modified to achieve repeatable donor ignition failed to allow successful initiation of the acceptor explosive when in the "arm" mode. The most probable cause of detonator failures containing a safe and arm mechanism is a loss of velocity of the impactor disc. This velocity loss may have been caused by

- (1) Frictional losses of the disc when traveling through the "arm" passageway of the S&A mechanism.
- (2) "Blow-by" of the gas products, providing a cushion between the impactor disc and the surface of the acceptor explosive charge.
- (3) Venting of the gas products, limiting the "gun-barrel" acceleration of the impactor disc.

Schedule constraints of the development program prevented additional tests to determine specific causes and pertinent solutions to achieve detonations when using safe and arm configurations.

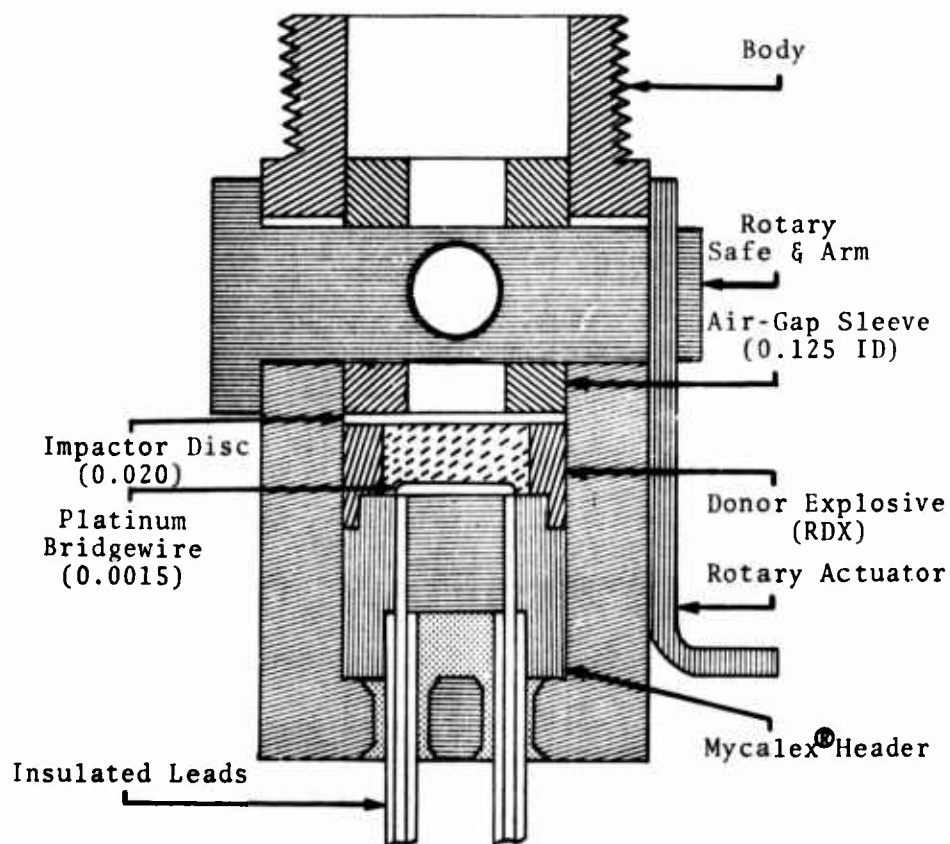
E. Feasibility Demonstration

The final detonator configuration used to demonstrate the feasibility concept (Figure 4) did not contain a safe and arm mechanism. Tests were not performed to verify the minimum no-fire currents of one ampere applied



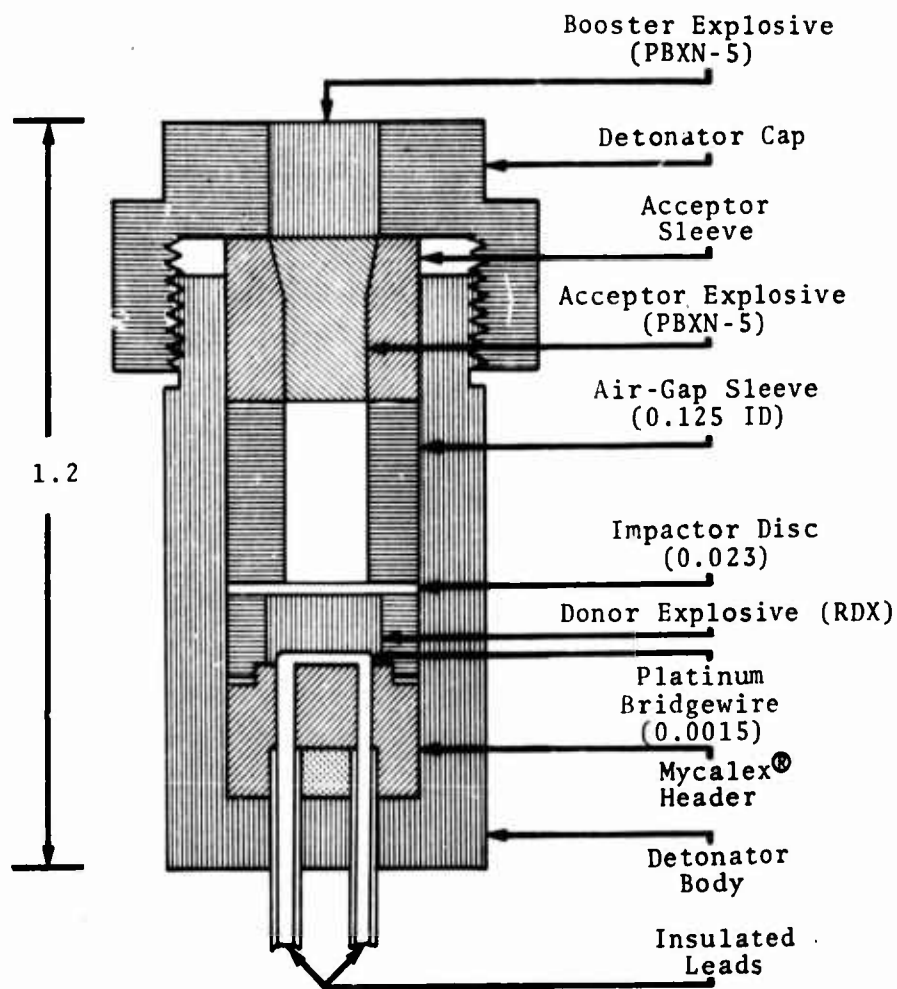
- Notes:
1. Acceptor charge and detonator cap not shown.
 2. Shown in safe position.
 3. Overall length without cap 1 inch.

Figure 2. Detonator Body with Pull-Pin Safe and Arm Mechanism



- Notes:
1. Acceptor charge and detonator cap not shown.
 2. Shown in safe position.
 3. Overall length without cap 1 inch.

Figure 3. Detonator Body with Rotary Safe and Arm Mechanism



Note: All dimensions in inches

Figure 4. Final Configuration for Feasibility Demonstration

for one minute. Five consecutive successful detonations using samples of this configuration tested in accordance with Test 301, MIL-STD-331, fulfilled the design specification. A comparison of pertinent design specifications and actual measured values is shown in Table III.

TABLE III. COMPARISON OF SPECIFIED DESIGN REQUIREMENTS AND MEASURED VALUES

Pertinent Requirement	Specified	Actual
1. Initiation	10 amperes (max)	10 amperes (max)
2. Performance (Dent)	0.010 inch (min)	0.039 inch (min)
3. Response Time	1 millisecond (max)	0.8 millisecond (max)

SECTION IV

CONCLUSIONS

An all-secondary-explosive, low-voltage, electric detonator will result from proper coupling of the following three processes:

- (1) Hot-wire initiation of a self-sustaining deflagration in a donor secondary explosive.
- (2) Release and acceleration of a metal impactor disc by confined product gases of the deflagration in the donor explosive.
- (3) Shock initiation-to-detonation of an acceptor secondary explosive upon impact by the accelerated impactor disc.

The crucial parameter for successful detonator operation is sufficient gas product containment to achieve the threshold pressure for self-sustaining deflagration of the donor explosive.

Variation of design parameters (air-gap length, impactor disc thickness, etc.) permits flexibility in meeting specific operational requirements.

The detonator design discussed in this report was sufficient to demonstrate feasibility. However, additional effort is necessary to convert this feasibility model into a production detonator with a demonstrated capability of operating reliably in extreme environments of temperature, humidity and, possibly, shock and vibrations. A production detonator implementing the basic concept would reduce the hazards of handling detonators to the same level as handling the main charge, and would permit safe mating of detonators with munition during manufacturing, simplifying logistics and field handling.

APPENDIX I

CONTRACTOR TEST PROCEDURES

All tests of the various detonator configurations were performed by contractor personnel at explosive test facilities of Reynold's Rocket Systems, La Puente, California.

Instrumentation for each test series (Figure I-1) used standard laboratory equipment and a special firing circuit designed and built by the contractor.

The firing current was calibrated prior to each test series. A dummy resistor, approximately equal to the cold resistance of the platinum bridgewire, was inserted across the detonator terminals in lieu of an actual detonator. An ammeter was placed across the ammeter terminals. The variable resistor was used to establish the desired firing current. After the firing current was established, the ammeter was removed and replaced with a shorting block. The actual detonator leads replaced the dummy load and the test began.

The power/reset switch (S₁) was turned on, applying +12 volts to the SCR. Initiation of the detonator was accomplished by depressing the fire switch (S₂) turning on the SCR, providing a no-bounce current to the detonator and generating a single sweep synchronization pulse for the oscilloscope.

Actual detonator firing current, as a function of time, was monitored as a developed voltage across a 0.1 ohm resistor. A pin switch containing a small air-gap was mounted on the outer surface of the booster charge. Ionization of air in the pin-switch gap, due to booster detonation, caused conduction indicating detonator response time.

Typical firing current and pin-switch waveforms are shown in Figure I-2. (The pin-switch channel utilized a reverse polarity display to generate the break in the timing base line.) The firing current wave shape reached the peak firing current rapidly and decayed from this maximum as the bridgewire resistance increased under localized temperature effects.

Holding Fixture per Test 301
(Used only for Design Proof
Test Series)

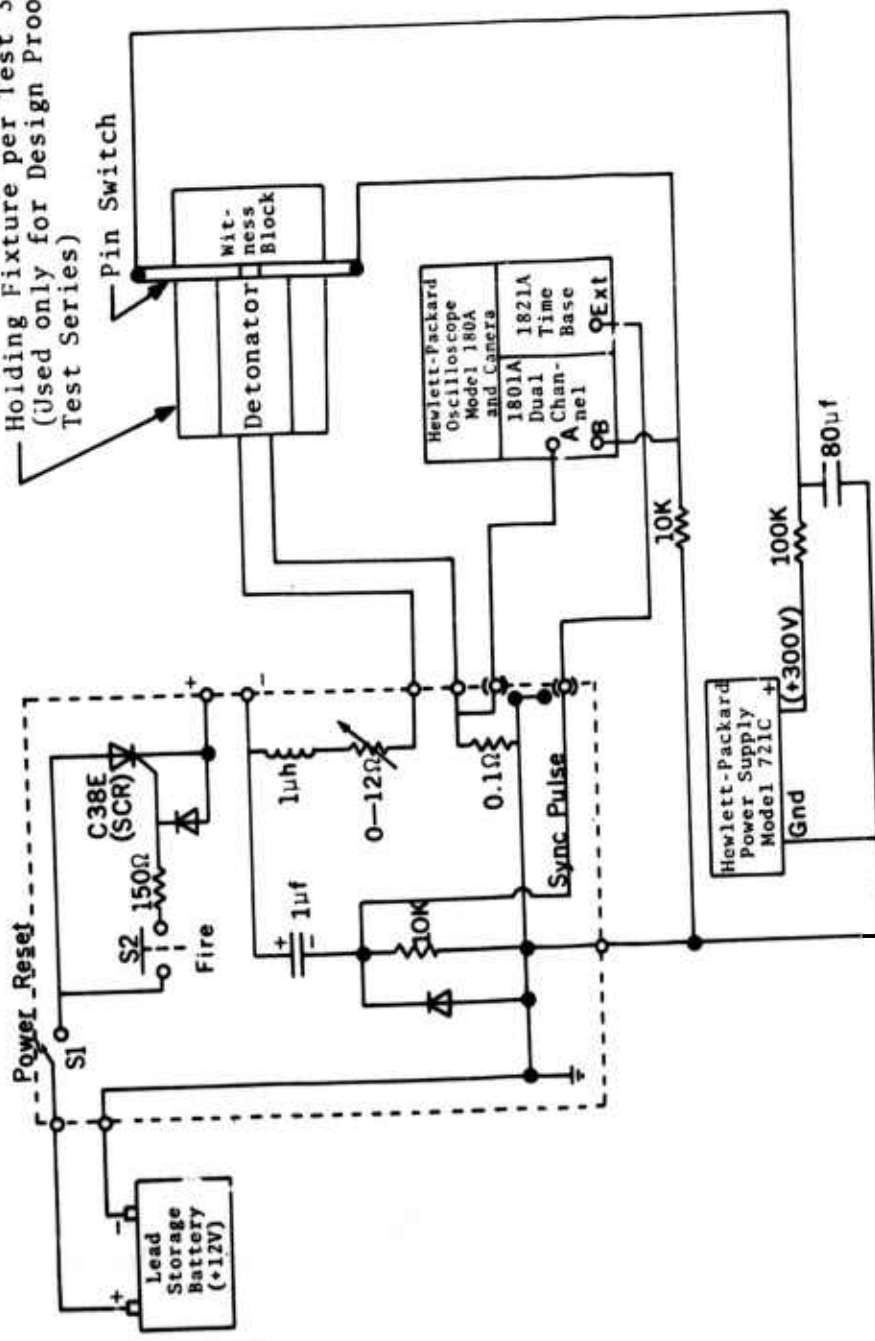


Figure I-1. Test Instrumentation

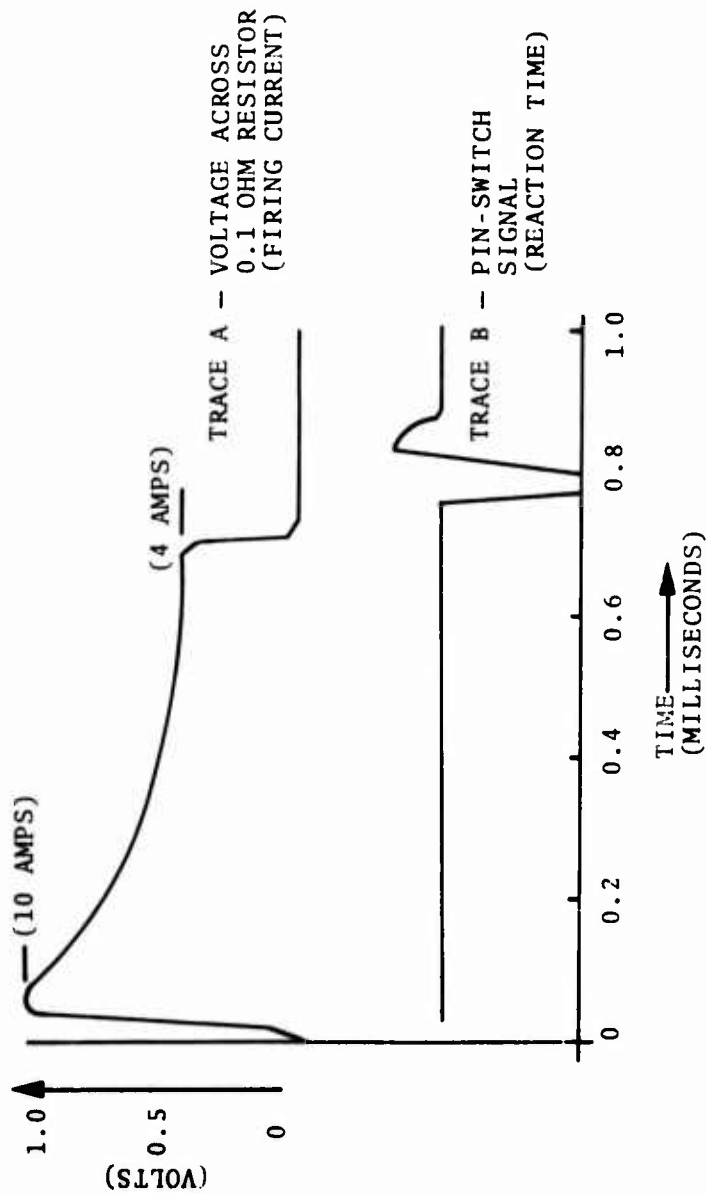


Figure I-2. Typical Oscilloscope Waveshapes

APPENDIX II

AIR FORCE TESTING

Eight prototype detonators furnished by Systems, Science and Software were function tested in the Armament Laboratory's Explosive Dynamics Laboratory. Procedures and results are outlined below.

- a. To insure compaction of the RDX donor charge, each detonator cap was tightened to 200 inch-pounds with a torque wrench prior to firing. The firing circuit for the tests was patterned after that used by Systems, Science and Software during the development program. Instrumentation consisted of a steel witness block to measure detonator output and a foil switch for measuring detonator function time. Function time was recorded on a Hewlett-Packard Model 5326A time interval counter and a Tektronix Model 555 oscilloscope with a Type K vertical amplifier. Function time was measured as the time difference between application of firing voltage and breakout of the acceptor charge which shorted the foil switch. The firing current for each test was monitored with a Tektronix Model 7704 oscilloscope with Type 7A12 and 7B71 plug-in units.
- b. Of the eight detonators tested, seven functioned properly. The detonator that did not function was disassembled and examined. The bridgewire had apparently separated from one post prior to complete ignition of the donor charge. The detonator bridgewire had been continuity tested prior to firing. Table II-1 shows the test results from each detonator.

TABLE II-1. TEST RESULTS

Detonator Number	Function Time	Output (1)
1	.815 m/sec	.041 inch
2	(2)	.039
3	(3)	(3)
4	.597	.038
5	(2)	.037
6	.577	.036
7	.566	.033
8	(2)	.035

- (1) Measured as depth in inches of a dent in a steel witness plate.
- (2) Function time not recorded.
- (3) Detonator did not function.

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13. ABSTRACT		
<p>The feasibility of an all-secondary explosive, low-voltage, electric detonator was demonstrated. The detonator consists essentially of a donor explosive combustion chamber, an impactor disc, an air-gap and an acceptor explosive column which provides for proper coupling of the following three critical processes:</p> <ol style="list-style-type: none"> 1. Hot-wire initiation of a self-sustaining deflagration in a "donor" secondary explosive. 2. Release and acceleration of a metal impactor disc by confined product gases of the deflagration in the donor secondary explosive. 3. Shock initiation-to-detonation of an acceptor secondary explosive upon impact by the accelerated impactor disc. <p>The design parameters controlling the critical processes are discussed. Unique safe and arm mechanisms, inherent in the basic detonator concept, were also investigated, and are described.</p>		

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